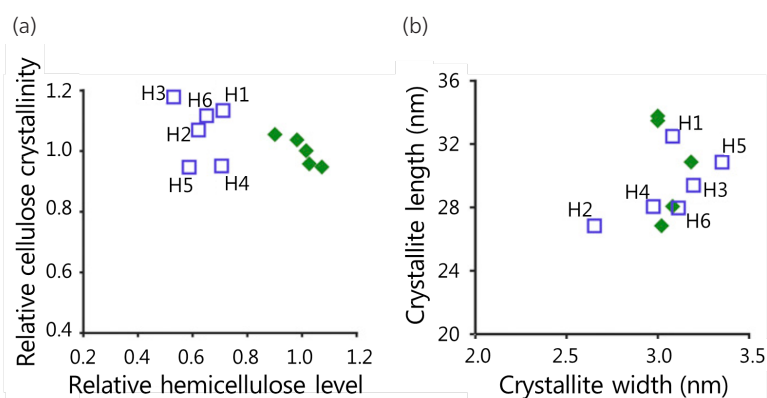


# Stradivari's Secret

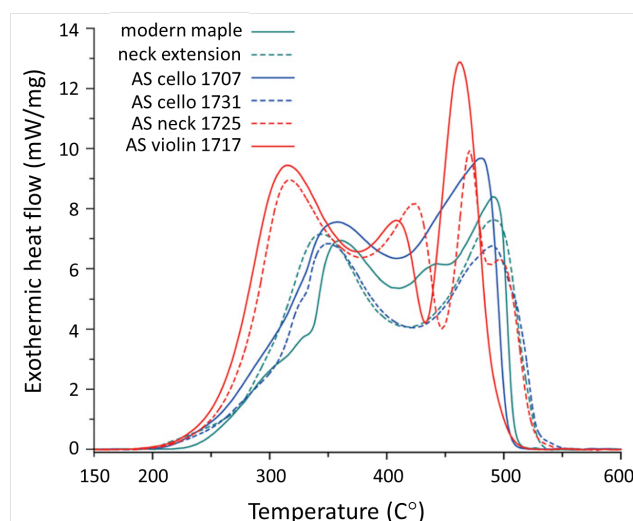
*Scientists have succeeded to show that the maple wood used for making the famous Stradivari violins exhibit unique chemical and physical properties, which are attributed to the combined effects of aging, chemical treatments and vibrations.*

The Stradivari violins, created by Antonio Stradivari in the late 17<sup>th</sup> and early 18<sup>th</sup> century, are considered to be one of the best set of violins in the world. However, the origin behind the sound quality of the Stradivari violins has remained a mystery. This is all the more intriguing because violins made by the following generations of the Stradivari family as well as other modern violins have not been able to match the Stradivari violins, according to music connoisseurs. In a very interesting, recent study, scientists have uncovered several unique properties of the maple wood used to make the Stradivari violins.

Using nuclear magnetic resonance, X-ray diffraction and differential scanning calorimetry, Hwan-Ching Tai (National Taiwan University) and his co-workers showed that the maple used by Stradivari violins and cellos exhibit unique features which are not observed in tonewood used to make modern violins. The authors could also confirm that the Stradivari violins were treated with complex mineral preservatives which contained Al, Ca, Cu, Na, K and Zn. The authors used nuclear magnetic resonance and synchrotron X-ray diffraction to show that while one-third of the hemicellulose had decomposed after nearly 300 years, accompanied by signs of lignin oxidation, but no apparent changes in cellulose could be detected in the experiments (Figs. 1(a) and 1(b)). The relative cellulose crystallinity plotted against relative hemicellulose levels measured by nuclear magnetic resonance was distinct for the Stradivari violins and cellos compared to other modern violins (Fig. 1(a)). However, the crystallite lengths and widths estimated from X-ray diffraction patterns were similar for all the types of violins and cellos investigated in the study (Fig. 1(b)). Further, only maples from the Stradivari violins exhibited unusual thermo-oxidation patterns, distinct from Stradivari cellos and natural modern maple wood (Fig. 1(c)). The authors could thus conclude that in their current state, the maple wood used for the Stradivari violins have very different chemical composition and properties compared to Stradivari cellos as well as modern violins. This was



**Fig. 1:** (a) Observed (crosses) and fitted (solid lines) neutron powder diffraction patterns taken at 80 K. (b) Schematic drawing of the proposed crystal-line structure of the Rb-Co-Fe in the core and the K-Ni-Cr shell. [Reproduced from Ref. 1]



**Fig. 2:** Differential scanning calorimetry thermograms of Stradivari violin compared to Stradivari cello and modern maple, showing a distinct behavior of the Stradivari violins. [Reproduced from Ref. 1]

attributed to the combined effects of aging, chemical treatments and vibrations.<sup>1</sup>

The authors hope that their study will inspire further investigations on tonewood processing for improving instrument making techniques in the future. (Reported by Ashish Chainani)

This report features the work of Hwan-Ching Tai and his co-workers published in PNAS **114**, 27 (2017).

### TLS 01C2 SWLS – X-ray Powder Diffraction

- X-ray Diffraction
- Materials Science

### Reference

1. H.-C. Tai, G.-C. Li, S.-J. Huang, C.-R. Jhu, J.-H. Chung, B. Y. Wang, C.-S. Hsu, B. Brandmair, D.-T. Chung, H. M. Chen, and J. C. C. Chan, PNAS **114**, 27 (2017).

The Chimei Museum, located in Tainan, Taiwan, has one of the largest and finest collections of violins in the world. The pictures of the Stradivari violin are provided by the courtesy of the Museum.



## Resonant Inelastic Excitations Lead the Way

*Resonant Inelastic X-ray Scattering (RIXS) is a very versatile probe for investigating emergent phenomena which originate from spin-charge-lattice coupling in strongly correlated electron systems. This article reports three classic RIXS studies on the electronic structure of: (i) the Verwey transition material magnetite  $\text{Fe}_3\text{O}_4$ , (ii) the spin-state transition in  $\text{LaCoO}_3$ , and (iii) the quasi two-dimensional Nickelates  $\text{La}_{2-x}\text{Sr}_x\text{NiO}_4$  ( $x = 0, 0.33, 0.45$ ).*

In this article, we discuss three valuable recent results which demonstrate the unique capabilities of Resonant Inelastic X-ray Scattering (RIXS) for revealing localized as well as dispersive spin-charge-orbital excitations with elemental and ionic-configuration specificity. **TLS 05A1** was developed to carry out momentum-resolved RIXS using the energy-compensation principle of grating dispersion for the active grating monochromator (AGM) and the active grating spectrometer (AGS). The design of the AGM-AGS system greatly enhances the measurement efficiency of inelastic soft X-ray scattering.<sup>1</sup> After long and sustained efforts, it is now possible to routinely carry out RIXS measurements at a good energy resolution and reasonable count rates. Temperature dependent (20–550 K) momentum-resolved RIXS can be carried out with an energy resolution of ~108 meV at the Ni  $L_3$ -edge (~850 eV). Using these capabilities, scientists have now succeeded to answer important long-standing questions on the electronic structure of strongly correlated transition metal oxides.

**(i) Magnetic polarons in magnetite ( $\text{Fe}_3\text{O}_4$ ):** Magnetite, or lodestone, is the first known magnet to mankind and was discussed in Greek and Chinese literature as early as the 4<sup>th</sup> to the 6<sup>th</sup> century BC. It

was used as a magnetic compass and the name ‘magnet’ most probably comes from Magnesia, an ancient city in Greece where lodestones were found. The properties of magnetite attract significant scientific and technological interest even today, because of its applications in ultrafast magnetic sensors, palaeomagnetism, nanomedicine, etc. Magnetite  $\text{Fe}_3\text{O}_4$  becomes ferrimagnetic below  $T_C = 850$  K, followed by an abrupt decrease in its electrical conductivity by two orders of magnitude as the temperature is cooled below  $T_V = 122$  K. The crystal structure of magnetite consists of tetrahedral  $\text{FeO}_4$  and octahedral  $\text{FeO}_6$  motifs. Within its unit cell, one-third of the total number of Fe sites (the so-called A-sites) are nominal  $\text{Fe}^{3+}$  ions tetrahedrally ( $T_d$ ) coordinated with oxygen atoms; the remaining two-thirds are termed B-sites with equal number of nominal  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  ions which are octahedrally ( $O_h$ ) coordinated with oxygen atoms. An  $\text{Fe}^{2+}$ – $\text{Fe}^{3+}$  charge-ordering occurring on the B-sites was first suggested by Verwey as the driving force of this transition.<sup>2</sup>

Although numerous investigations have been carried out to verify the charge localization on the B-sites in the low temperature phase, the precursor to the charge-ordering pattern of magnetite in the high